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Accelerator Division
Technical Note

AGS/AD/Tech. Note No. 414

RADIATION PROTECTION STUDIES DURING HIGH INTENSITY RUNNING AT AGS

RADIATION EXPOSURE AROUND THE AGS RING AND IN THE SEB EXPERIMENTAL AREAS

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Radiation Protection Studies During High Intensity Running At AGS

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Summary

On February 9 and 10, 1995, the AGS Department and pertinent S&EP Division staffs undertook studies of neutron and gamma dose rates in and around the AGS Complex during high-intensity proton running. The relationship of dose rate to machine intensity, and the neutron and gamma components of the radiation field were studied. The use of various radiation-weighting-factors for neutrons was reviewed. Airborne contamination at the target gates and radiation exposure from a cooling tower plume were observed and measured.

The study indicated that the AGS Department should add shielding to trenches at the EEA Ramp and the trench running through the Old D Gate Crotch. This concern was brought to the attention of the Head of the Experimental Areas Group and the Radiation Safety Committee (RSC). The shields around AGS Ring escape hatches, the South Plug Door, the North Plug Door and North Catwalk should be upgraded. This was discussed with a sub-Committee of the RSC and temporary shielding was added to the South Plug Door ramp. Final shield design shall go before the full Committee.

Reduced occupancy of certain areas such as the B5 Condo and the Target Desk was considered important in order to avoid unwarranted dose. Thus, the Target Desk occupancy has been limited and the liaison physicist for the B5 Line has been apprised of the situation at the B5 Condo.

The set point of certain alarming chipmunks needed to be changed in order to allow continuous and safe operation. The use of Chipmunks in unoccupied, secured areas that are continuously in the alarm state needs to be re-evaluated. Certain chipmunks needed to be shielded from shine from water pipes since it was interfering with their primary protection mode which is to detect beam faults. These concerns have been reviewed by the RSC and they shall follow-up.

Efforts should be undertaken by HP staff at AGS to ensure that the posted dose rate accurately reflects the total dose rate. Postings do not report the correct proportion of neutron and gamma dose particularly near water manifolds. Quality factor measurements appear sufficient for the most part; however, a few additional quality factor measurements could be performed in the A2 and C1 Lines. The Head of the S&EP Facility Support Section (FSS) has been apprised of these concerns.

The dose to staff in Building 911 from cooling tower plumes is estimated to be less than 3 mrem per 20 week running period. However, the AGS Department needs to fully characterize the gamma shine from the cooling tower plumes. The FSS is assisting in this effort by placing environmental dosimeters in offices in Building 911 and other similar areas. The ad hoc AGS Committee for Cooling Water Shielding was apprised of these recent measurements, and has begun the process of reviewing long-term and short-term options for dose reduction.

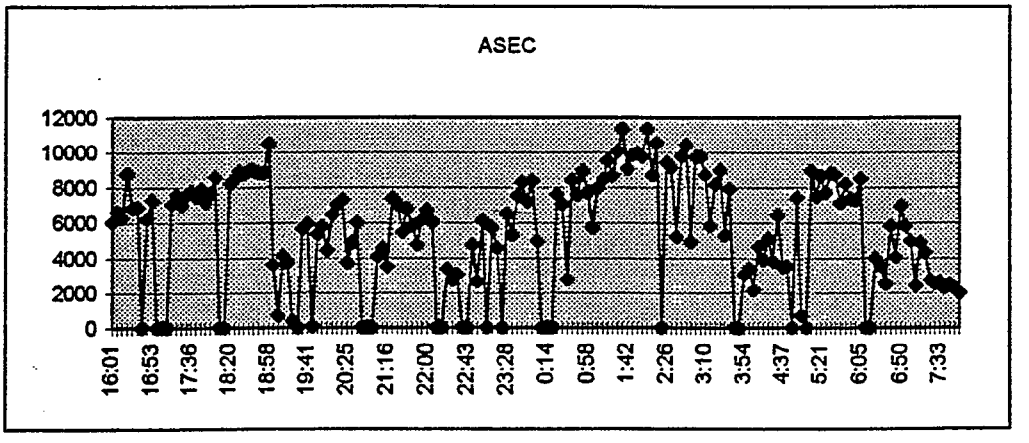
A1 Line, E852

Radiation Weighting Factor Measurements

Radiation weighting factors, often called quality factors or Q, are determined from measurements normally made by HP staff at AGS with a BF_3 tube and a GM tube. The BF_3 tube is sensitive to neutrons, and the GM tube is predominantly sensitive photons and muons. Other studies by health physicists from the S&EP Division employ more complex instruments and analysis. No measurements were taken during this study period at this location.

Prior measurements were made in 1993 by J. Preisig of the S&EP Division using a Bonner-Multisphere LiI Spectrometer and a C-11 plastic scintillator. These have shown the radiation weighting factor for neutrons in this area to range up to 6.3. However, neutrons were a small fraction of the mixed radiation field at this location; that is, gamma radiation near the A1 Line that dominated the total dose rate.

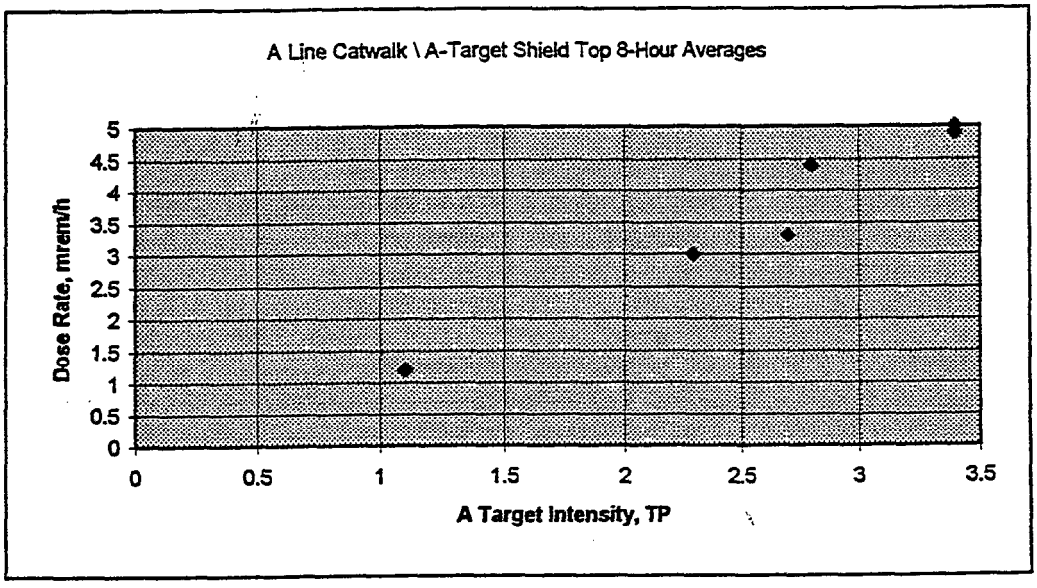
Instantaneous Measurements



Average Area Dose Rate and Intensity

The eight-hour average was recorded by area radiation monitors. The radiation weighting factor used in these instruments is pre-set to a value of 2.5. The chipmunk sees an absorbed dose rate, in mrad/h, and we assume it is from a mixed radiation field of half gamma and half neutron. We assume Q=5 for the neutron component and Q=1 for the gamma component. The instrument multiplies the absorbed dose by 2.5 in order to give a response in mrem/h. The results for this area were:

Date/Time	A Target Intensity, 8 hour average, TP	A Line Catwalk \ A-Target Shield Top, (44) 8 hour average, mrem/h
Feb 9, 0 to 8	2.8	4.4
Feb 9, 8 to 4	2.7	3.3
Feb 9, 4 to 12	3.4	5.0
Feb 10, 0 to 8	3.4	4.9
Feb 10, 8 to 4	2.3	3.0
Feb 10, 4 to 12	1.1	1.2



Survey Instrument Measurements

During the 16-hour study period, spot surveys were performed at or near the A and A1 Lines with an HP1010 survey meter that has a radiation weighting factor set at 5. The maximum radiation level was observed in the A Line and was 60 mrem/h at 4.5 TP.

The A1 area survey with an HP1010 indicated levels as high as 12 mrem/h near the A1 beam pipe that is adjacent to the B2 Test Beam area. This particular portion of the A1 Line has a direct view of the water manifold near the B Upstream Target Gate. The intensity in A1 was 1.6×10^6 particles per pulse. Levels at the entrance to the MPS Control Room, which is at the end of the A1 Line, were 0.6 mrem/h.

A2 Line, E865

Radiation Weighting Factor Measurements

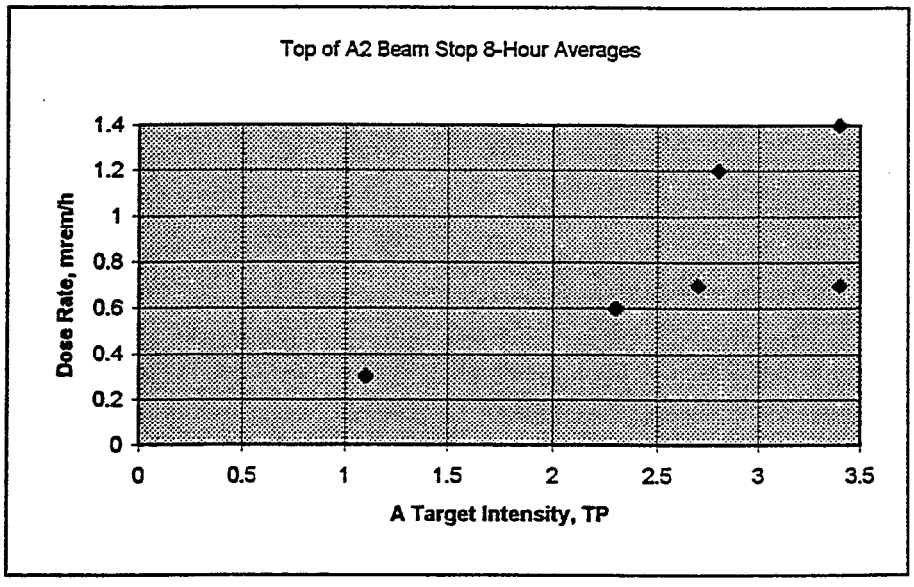
Downstream of A2 beam dump, the radiation weighting factor equaled 1. The particles leaving the beam dump are believed to be muons. There does not appear to be recent radiation weighting factor measurements near the A2 Line areas. A study in 1992 by J.

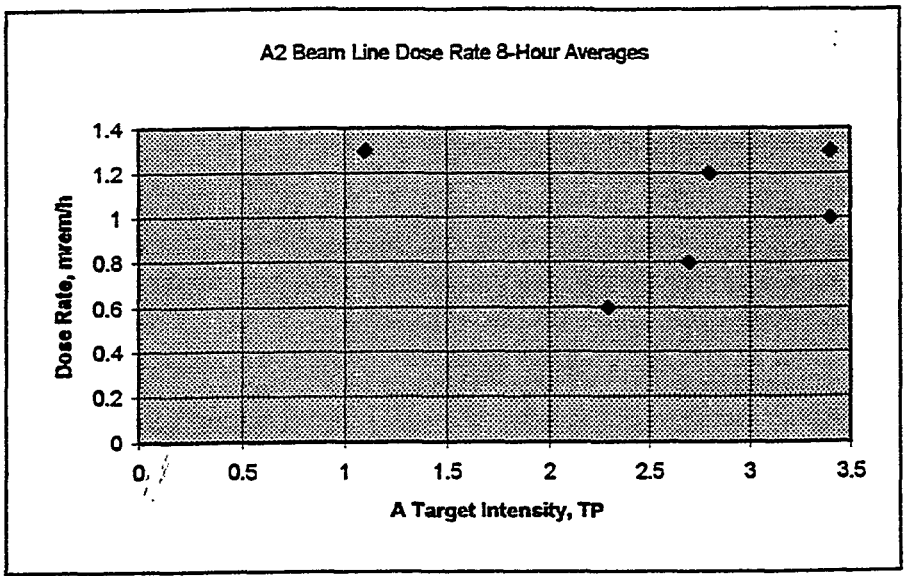
Preisig, when the area was configured differently, showed the radiation weighting factor for neutrons to be 5.

Average Area Dose Rate and Intensity

The eight-hour average was recorded by area radiation monitors. The radiation weighting factor used in these instruments is set at 2.5 since the radiation is assumed to be a mixture of photons and neutrons. The results for this area were:

Date/Time	A Target Intensity, 8 hour average, TP	Top of A2 Beam Stop, (52) 8 hour average, mrem/h	A2 Beam Line Dose Rate, (53) 8 hour average, mrem/h
Feb 9, 0 to 8	2.8	1.2	1.2
Feb 9, 8 to 4	2.7	0.7	0.8
Feb 9, 4 to 12	3.4	1.4	1.3
Feb 10, 0 to 8	3.4	0.7	1.0
Feb 10, 8 to 4	2.3	0.6	0.6
Feb 10, 4 to 12	1.1	0.3	1.3





Film Badge Measurements

Badge Number	Location For 16 Hours, Feb. 9 and 10, 1995	Beta Gamma / Neutron Dose, mrem
68481	E865 Counting House, Ceiling Over Desk	<10/<20

On the basis of the film-badge measurement, gamma dose rates were less than 0.6 mrem/h and neutron dose rates were less than 1.3 mrem/h.

Survey Instrument Measurements

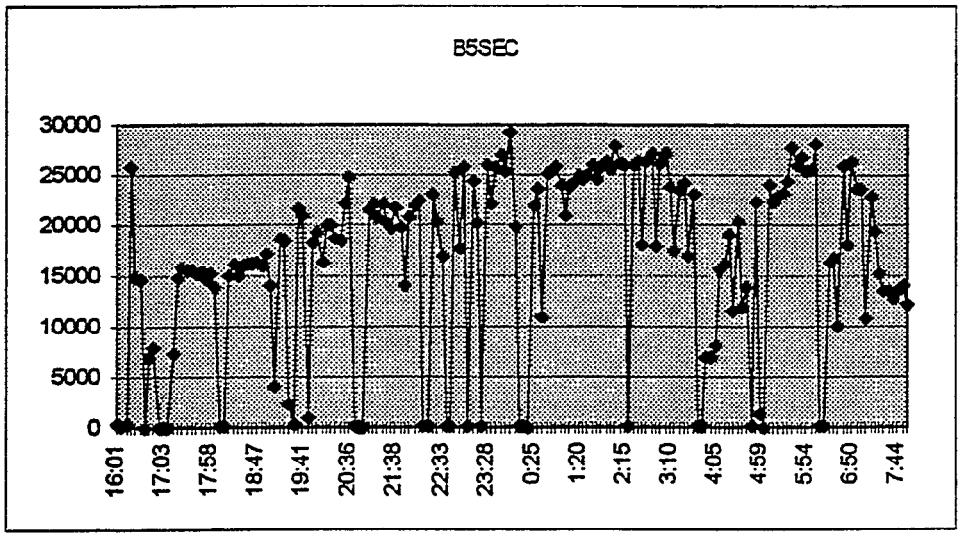
On Feb. 16, a fault study was performed in the E865 area at 10 TP. The occupied areas were 1.1 mrem/h with the A2 collimator closed, and 2.2 mrem/h with the collimator open. The survey was performed with an HP1010 which has a radiation weighting factor set at 5. The maximum level seen was 90 mrem/h at the beam dump and 32 mrem/h at upstream end of beam dump. At the bridge, a chipmunk recorded 25 mrem/h with the A2 collimator open.

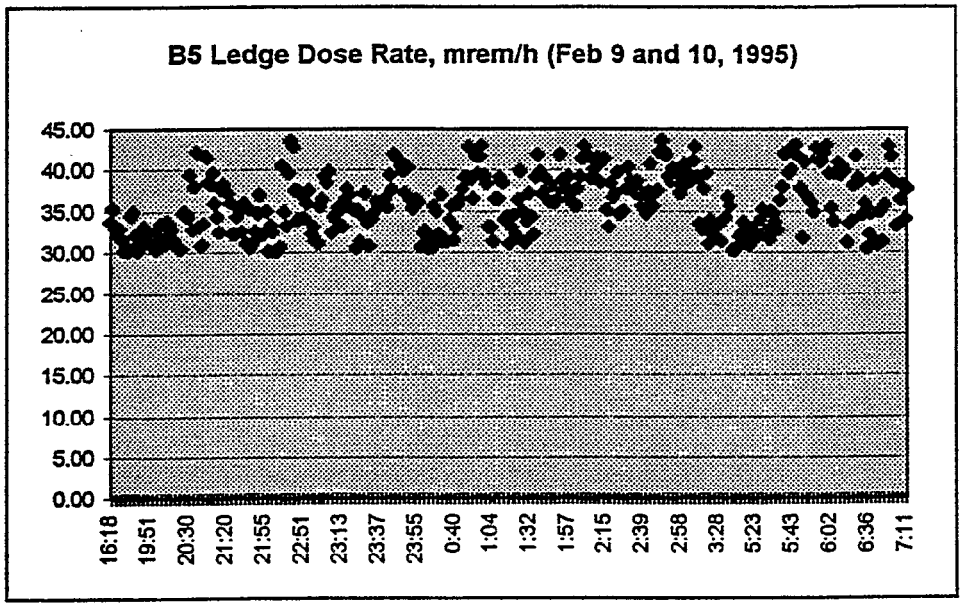
B5 Condo, E871

Radiation Weighting Factor Measurements

A radiation weighting factor measurement was made at the B5 Condo with 18 TP reported to be on target on Feb. 10, 1995. The Q was measured to be 3.3. No previous records for radiation weighting factor for this area were located.

Instantaneous Measurements

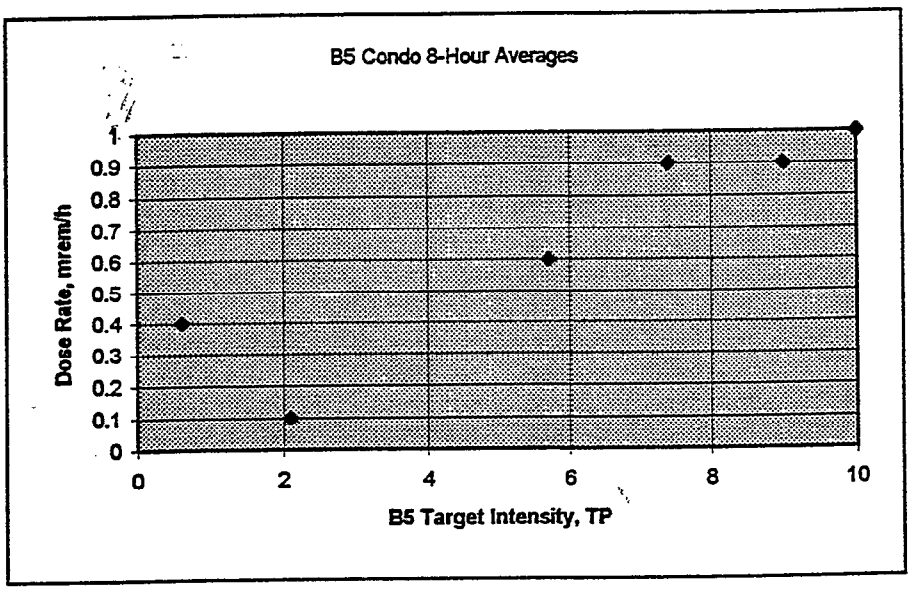


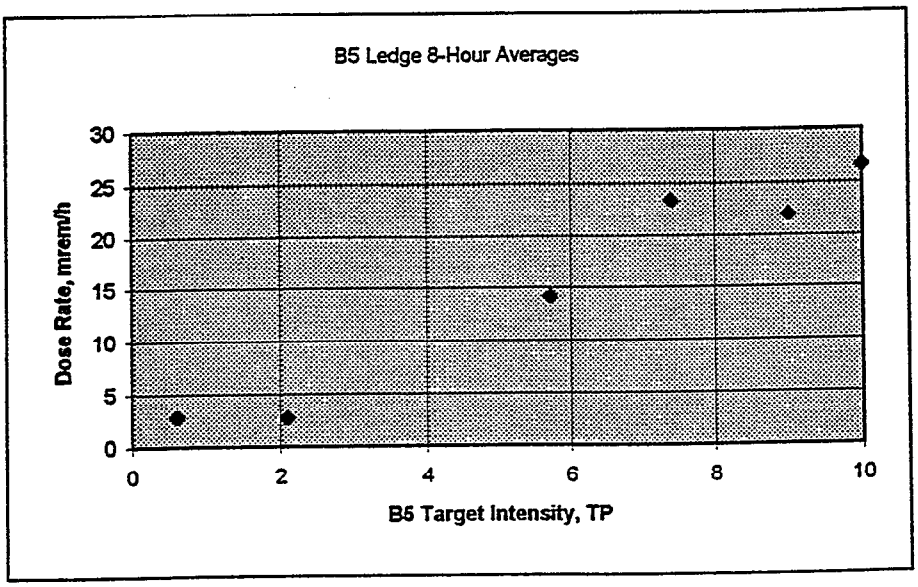


Average Area Dose Rate and Intensity

The eight-hour average was recorded by area radiation monitors. The radiation weighting factor used in these instruments is 2.5 since the radiation is assumed to be a mixture of photons and neutrons. The results for this area were:

Date/Time	B5 Target Intensity, 8 hour average, TP	B5 Condo Dose Rate, (33) 8 hour average, mrem/h	B5 Ledge Dose Rate, (34) 8 hour average, mrem/h
Feb 9, 0 to 8	7.4	0.9	23.4
Feb 9, 8 to 4	0.6	0.4	2.8
Feb 9, 4 to 12	9.0	0.9	22
Feb 10, 0 to 8	10	1.0	26.6
Feb 10, 8 to 4	5.7	0.6	14.2
Feb 10, 4 to 12	2.1	0.1	2.7





Film-Badge Measurements

Badge Number	Location For 16 Hours, Feb. 9 and 10, 1995	Beta Gamma / Neutron Dose, mrem
68485	E871 Condo, Second Floor, Control Console	<10/<20
68486	E871 Condo, Second Floor, South Wall	<10/<20
68487	E871 Condo, First Floor, Level 2 Room, Equipment Rack	<10/<20

On the basis of the film-badge measurement, gamma dose rates were less than 0.6 mrem/h and neutron dose rates were less than 1.3 mrem/h in the occupied areas.

Survey Instrument Measurements

During the 16 hour study period, spot surveys were performed at or near the B5 Condo with an HP1010 survey meter. Levels were observed to be 2 to 3 mrem/h in occupied areas. Outside the Condo, the maximum radiation level was observed in the B upstream area and was 10 mrem/h at 16 TP.

The B5 Condo was also surveyed on February 16 and the dose rates in the occupied areas ranged from 1.2 to 4.5 mrem/h. The general area was about 2.5 mrem/h. The intensity was reported to be 20 TP at this time.

During the study period, spot surveys were performed at or near the B5 beam stop with an HP1010 survey meter. Levels were observed to be 0.5 mrem per hour.

Levels of 1.5 to 5 mrem/h were measured in the secondary beam enclosure used for the B1 Beam Line which is contiguous to the B5 enclosure. The experiment in B1, E866, is not running at this time but is expected to run during the next heavy ion period.

B2 Test Beam

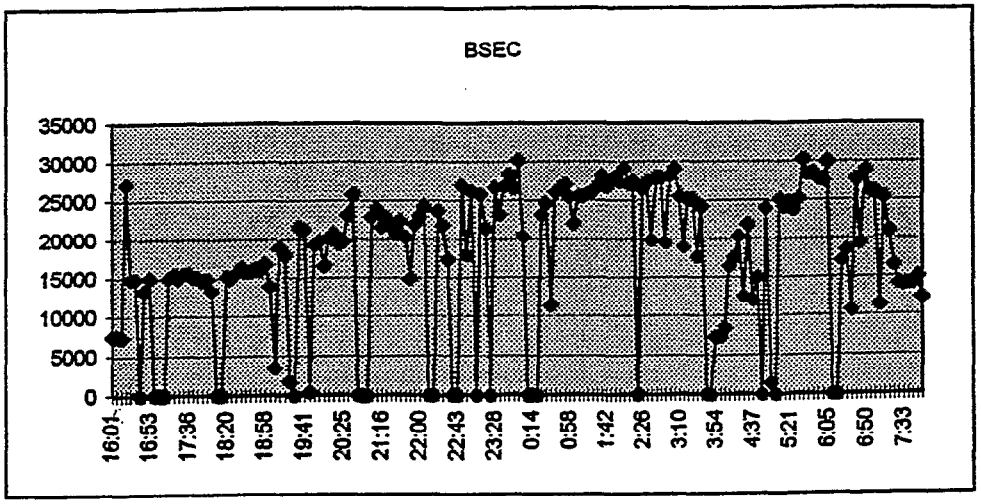
Radiation Weighting Factor Measurements

Radiation weighting factor measurements were made in the upstream Test Beam area near the water manifold near Chipmunk 35. The HP Technicians measured the radiation weighting factor to be 1.5 near the water manifold.

Away from the water manifold and at a distance downstream of about 25 feet, the radiation weighting factor was 5.2 for the neutrons as measured using a Bonner Multisphere Spectrometer on February 22. The neutron dose rate was 1.1 mrem/h. The gamma dose rate at this location was about 2 mrem/h.

Measurements made in 1992 by J. Preisig show the radiation weighting factor to be 6.7 near the B Target Upstream Gate, which is near the water manifold.

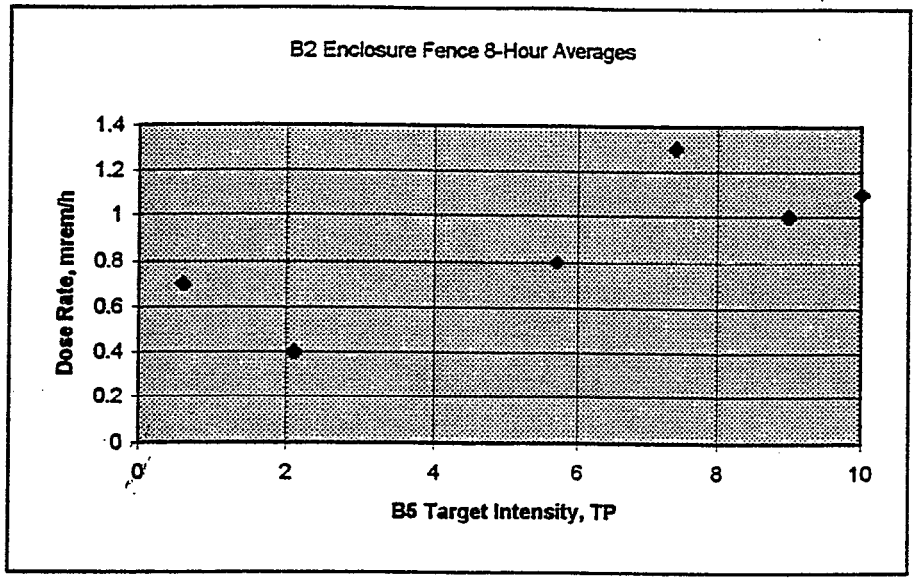
Instantaneous Measurements

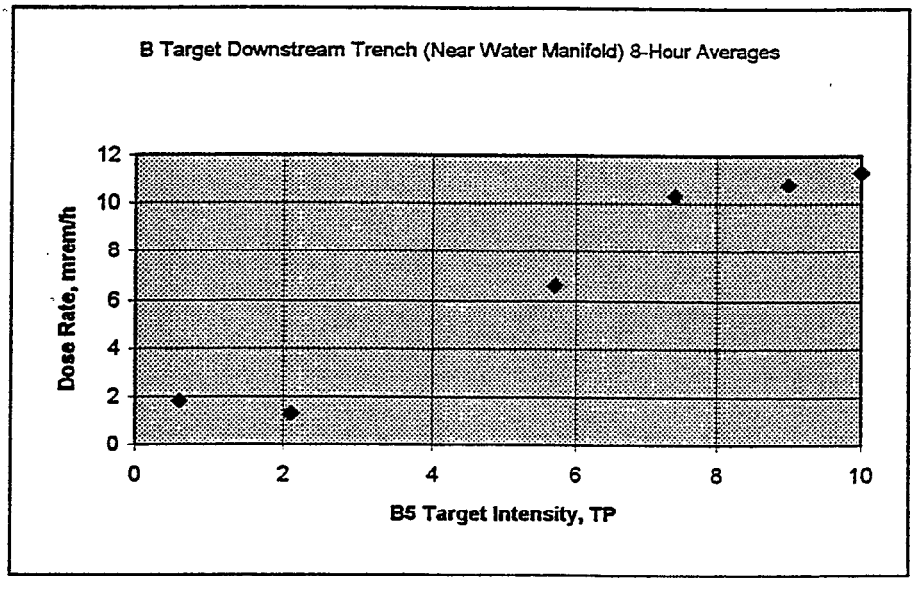


Average Area Dose Rate and Intensity

The eight-hour average was recorded by area radiation monitors. The radiation weighting factor used in these instruments is 2.5 since the radiation is assumed to be a mixture of photons and neutrons. The results for this area were:

Date/Time	B5 Target Intensity, 8 hour average, TP	B2 Enclosure Fence, (15) 8 hour average, mrem/h	B Target Downstream Trench, (35) (Near Water Manifold) 8 hour average, mrem/h
Feb 9, 0 to 8	7.4	1.3	10.3
Feb 9, 8 to 4	0.6	0.7	1.8
Feb 9, 4 to 12	9.0	1.0	10.8
Feb 10, 0 to 8	10	1.1	11.3
Feb 10, 8 to 4	5.7	0.8	6.6
Feb 10, 4 to 12	2.1	0.4	1.3





Film Badge Measurements

Badge Number	Location For 16 Hours, Feb. 9 and 10, 1995	Beta Gamma / Neutron Dose, mrem
68482	Chipmunk 35 near water manifold near B2 Test Beam.	60/<20
68483	B2 Test Beam about 1/2 way down the fenced area.	<10/<20
68484	B2 Test Beam Experimental Gate.	<10/<20

On the basis of the film-badge measurements, the average neutron dose rate was less than 1.3 mrem/h in the B2 Test Beam area.

The average gamma dose rate recorded by the film badge near the water manifold was about 4 mrem/h. Since the chipmunk response to gamma radiation is forced to be 2.5 times greater than the film badge, the chipmunk near the water manifold is in agreement with this film-badge result.

The average gamma dose rate along the B2 Test Beam fenced area was less than 0.6 mrem/h during the study period.

Survey Instrument Measurements

A survey of the Test Beam Area was made using a HP1010 which has a radiation weighting factor set at 5. The levels ranged from 2 to 3 mrem/h along the Test Beam fenced area in the area normally occupied by Users where mixed radiation is likely. The maximum dose rate observed along this fence was 10 mrem/h with 16 TP in B Line. The dose rate at a desk located near a water manifold at the upstream end of the Test Beam was measured to be 11 mrem/h using the HP1010. If the HP1010 response was primarily from photons from the nearby activated water, then the dose rate at this particular desk was actually 2 to 3 mrem/h. This is in reasonable agreement with the average gamma dose rate derived from film-badge measurements at this location. The majority of other desks in the Test Beam are located in a mixed radiation field, however.

Contamination

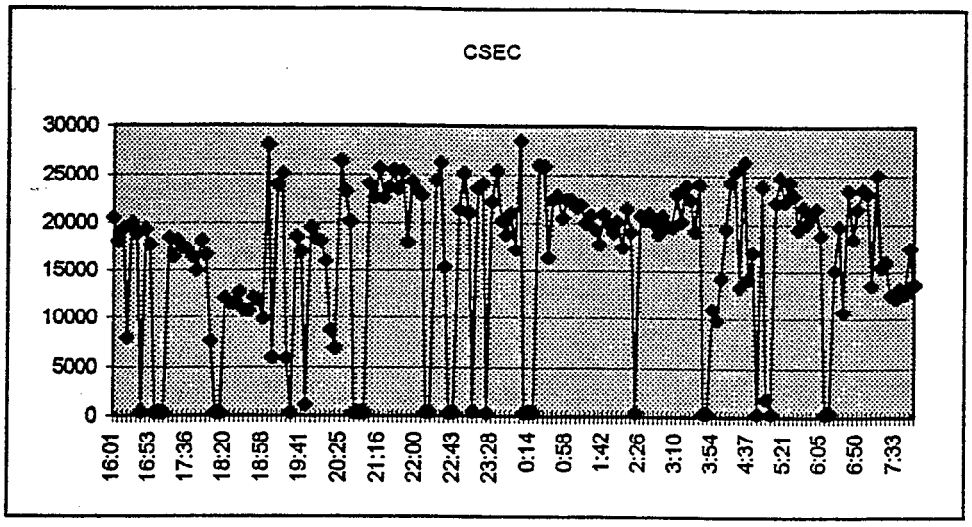
At about midnight February 9, air samples near the B Target Gate near Chipmunk 35 showed gross beta concentrations of 1.2×10^{-9} and 4.1×10^{-10} μCi. This corresponds to 1.5×10^{-5} and 5×10^{-6} mrem/h assuming the nuclide is C-11 which was likely. One of the work desks in the B2 Test Beam near the B Gate showed 1,100 dpm.

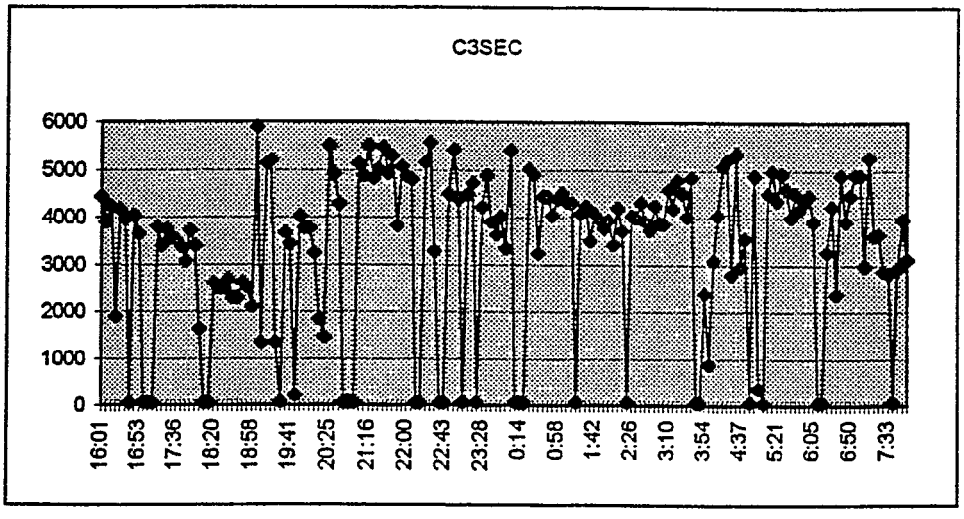
C1, E850

Radiation Weighting Factor Measurements

No radiation weighting factor measurements were made during this study. Previous studies of radiation weighting factor for this area were not located.

Instantaneous Measurements

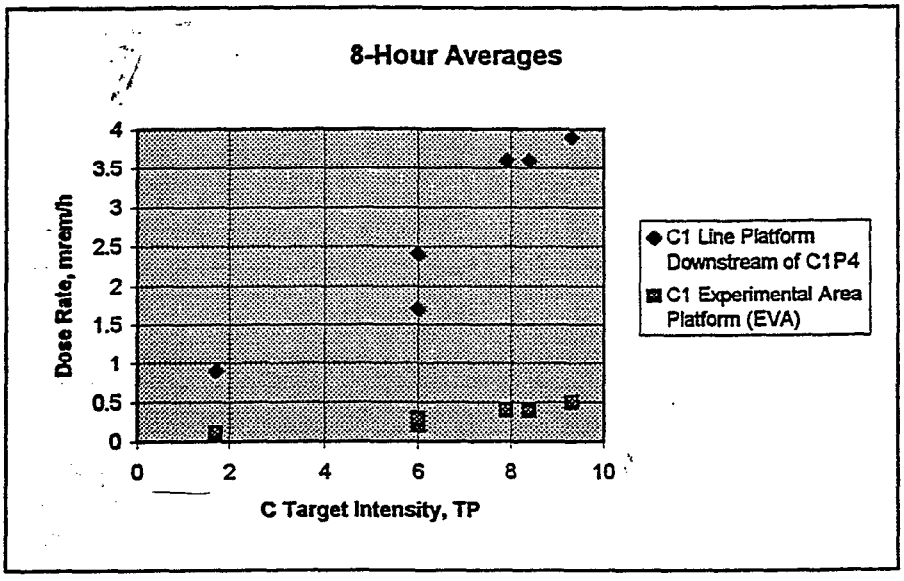


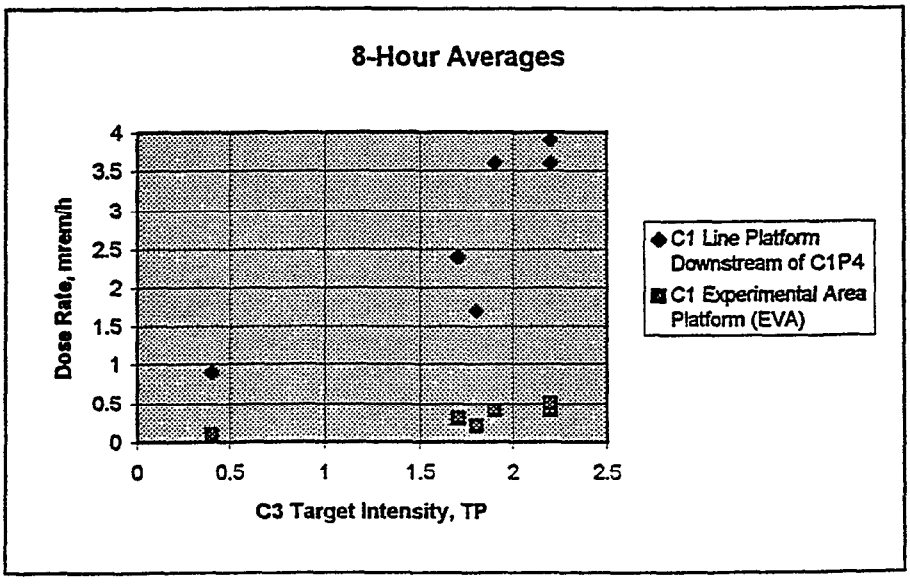


Average Area Dose Rate and Intensity

The eight-hour average was recorded by area radiation monitors. The radiation weighting factor used in these instruments is 2.5 since the radiation is assumed to be a mixture of photons and neutrons. The results for this area were:

Date/Time	C Target Intensity, 8 hour average, TP	C3 Target Intensity, 8 Hour Average, TP	C1 Line Platform Downstream of C1P4, (70) 8 hour average, mrem/h	C1 Experimental Area Platform (EVA), (71) 8 hour average, mrem/h
Feb 9, 0 to 8	7.9	1.9	3.6	0.4
Feb 9, 8 to 4	6.0	1.8	1.7	0.2
Feb 9, 4 to 12	8.4	2.2	3.6	0.4
Feb 10, 0 to 8	9.3	2.2	3.9	0.5
Feb 10, 8 to 4	6.0	1.7	2.4	0.3
Feb 10, 4 to 12	1.7	0.4	0.9	0.1





Film Badge Measurements

Badge Number	Location For 16 Hours, Feb. 9 and 10, 1995	Beta Gamma / Neutron Dose, mrem
68488	E850 Trailer.	<10/<20

On the basis of the film-badge measurements, the neutron dose rate was less than 1.3 mrem/h. The gamma dose rate was less than 0.6 mrem/h during the study period.

Survey Instrument Measurements

During the study period, spot surveys were performed at or near the C1 beam stop with an HP1010 survey meter. The radiation weighting factor for this instrument is set at 5. Levels were observed to be 0.4 mrem per hour.

C8, E890

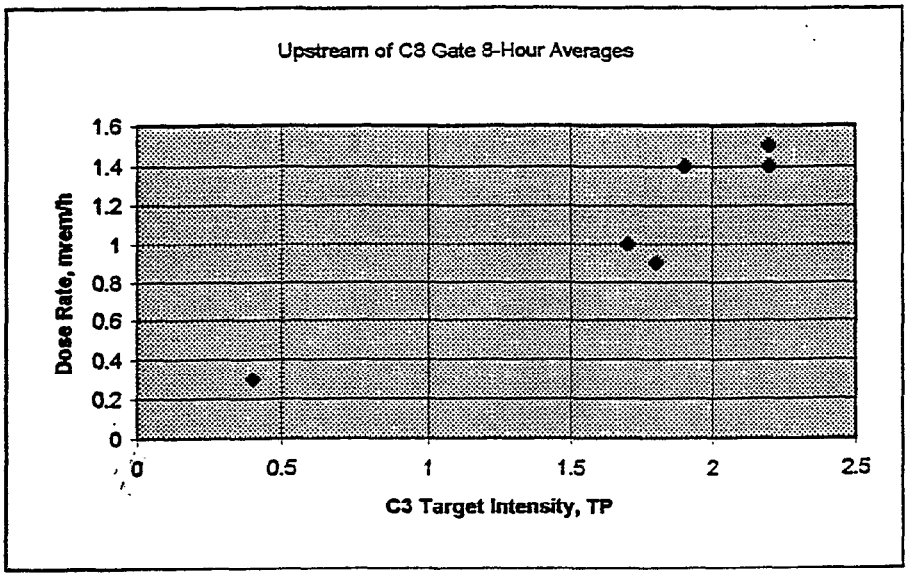
Radiation Weighting Factor Measurements

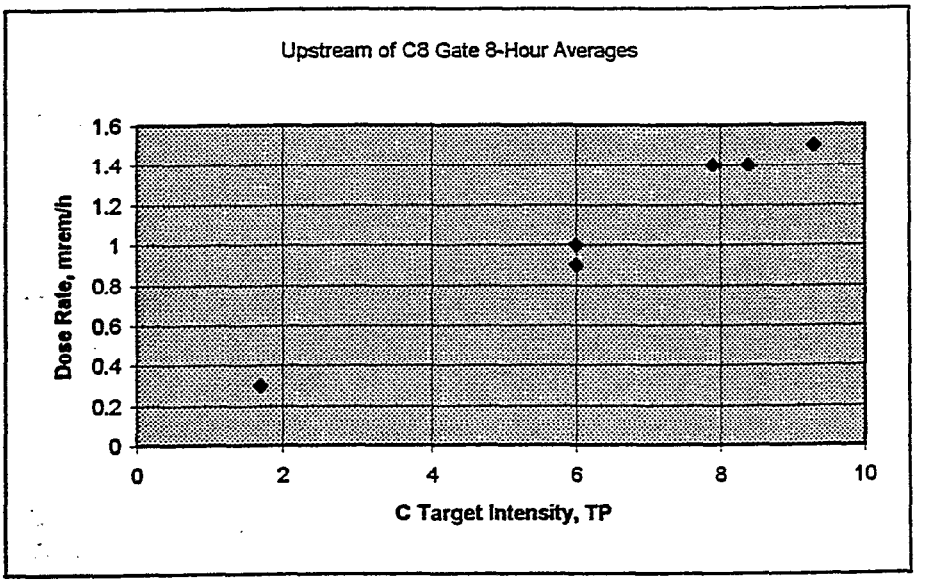
None were made during this study period. During 1994, J. Preisig measured a radiation weighting factor of 5.8 for neutrons in this area.

Average Area Dose Rate and Intensity

The eight-hour average was recorded by nearby area-radiation monitors. The radiation weighting factor used in these instruments is 2.5 since the radiation is assumed to be a mixture of photons and neutrons. The results for this area were:

Date/Time	C Target Intensity, 8 hour average, TP	C3 Target Intensity, 8 Hour Average, TP	Upstream of C8 Gate, (74) 8 hour average, mrem/h
Feb 9, 0 to 8	7.9	1.9	1.4
Feb 9, 8 to 4	6.0	1.8	0.9
Feb 9, 4 to 12	8.4	2.2	1.4
Feb 10, 0 to 8	9.3	2.2	1.5
Feb 10, 8 to 4	6.0	1.7	1.0
Feb 10, 4 to 12	1.7	0.4	0.3





Film Badge Measurements

Badge Number	Location For 16 Hours, Feb. 9 and 10, 1995	Beta Gamma / Neutron Dose, mrem
68493	E890 Trailer.	<10/<20
68494	Bottle Rack near Cooling Tower 2	80/<20
68489	C3 Target Gate	50/<20

On the basis of the film-badge measurements, the neutron dose rate was less than 1.3 mrem/h. The average gamma dose rate at the bottle storage rack near Cooling Tower 2 was 5 mrem/h during the study period. This Tower is across the street from Building 912, and about 60 feet from the E890 trailer. The gamma dose rate in the E890 trailer was less than 0.6 mrem/h on the basis of film badge measurements.

The C3 Target Gate is located in an area where a spot check using the HP1010 indicated 18 mrem/h. This film badge had a view of the nearby water-cooled bus that indicated 56 mrem/h on the HP1010. Thus, the film badge average of 3.1 mrem/h gamma compares with the HP1010 measurement.

Survey Instrument Measurements

During the study period, spot surveys were performed at or near the E890 trailer with an HP1010 survey meter. The radiation weighting factor for this instrument is set at 5. Levels in the E890 trailer were observed to be 3.4 to 4.2 mrem per hour sometime between midnight February 9 and 5:15 AM on February 10. Assuming the HP1010 is responding to the photon radiation from Cooling Tower 2, then this would translate into 0.7 to 0.8 mrem/h in the E890 trailer. This level was measured during the highest intensity period of the study.

The HP1010 measurements which were weighted for neutrons rose to 5.6 mrem/h in the roadway between Cooling Tower 2 and E890, and were 20 to 30 mrem/h near the bottle rack. For gamma radiation, this translates to 1 mrem/h in the roadway and 4 to 6 mrem/h at the bottle rack near the cooling tower.

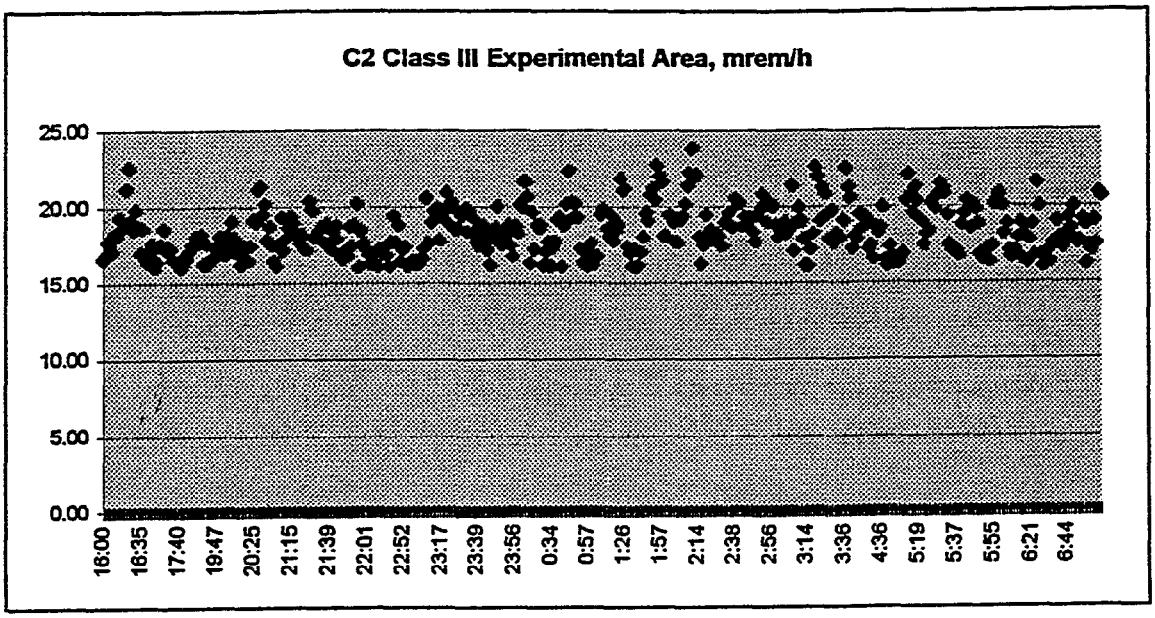
The maximum dose rate along the C Line was about 77 mrem/h using the HP1010 near the water-cooled bus area. The level is probably closer to 15 mrem/h. Weighted HP1010 rates as high as 12 to 13 mrem/h were measured on the C8 platform. Weighted HP 1010 rates along the primary beam shield walls from E787 to E890 ranged between 10 and 20 mrem/h.

C4, E787

Radiation Weighting Factor Measurements

None were made during this study period. During 1994, J. Preisig measured a radiation weighting factor of 5.8 for neutrons in this area.

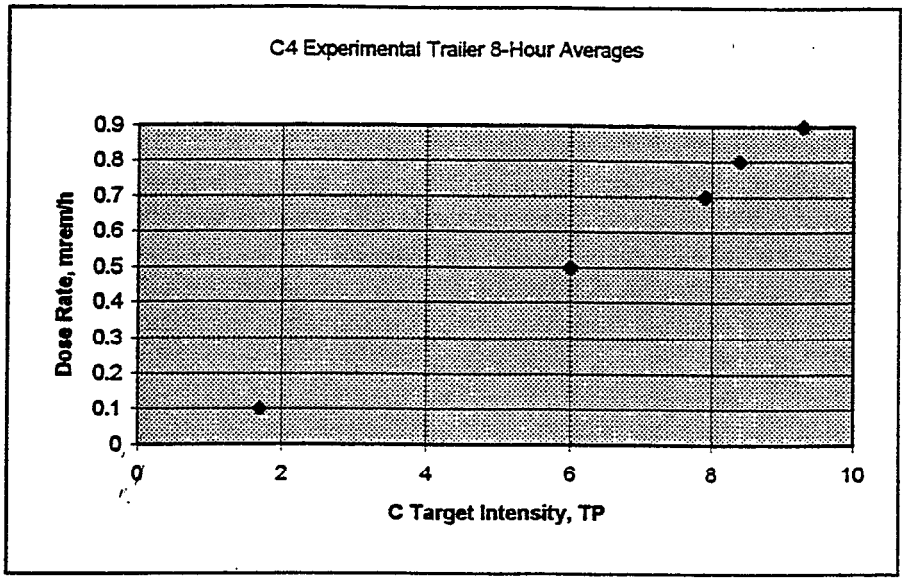
Instantaneous Measurements

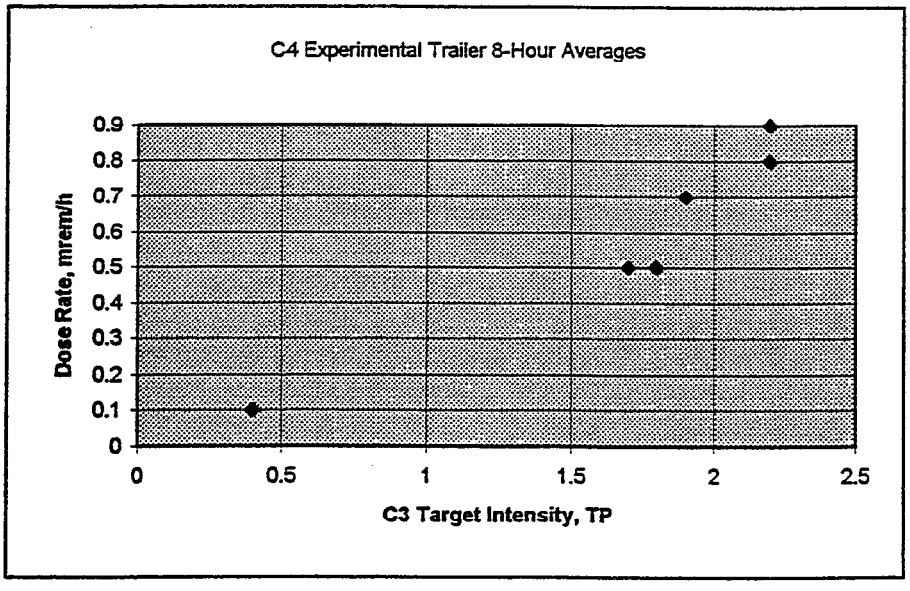


Average Area Dose Rate and Intensity

The eight-hour average was recorded by nearby area-radiation monitors. The radiation weighting factor used in these instruments is 2.5 since the radiation is assumed to be a mixture of photons and neutrons. The results for this area were:

Date/Time	C Target Intensity, 8 hour average, TP	C3 Target Intensity, 8 Hour Average, TP	C4 Experimental Trailer, (37) 8 hour average, mrem/h
Feb 9, 0 to 8	7.9	1.9	0.7
Feb 9, 8 to 4	6.0	1.8	0.5
Feb 9, 4 to 12	8.4	2.2	0.8
Feb 10, 0 to 8	9.3	2.2	0.9
Feb 10, 8 to 4	6.0	1.7	0.5
Feb 10, 4 to 12	1.7	0.4	0.1





Film Badge Measurements

Badge Number	Location For 16 Hours, Feb. 9 and 10, 1995	Beta Gamma / Neutron Dose, mrem
68490	E787 Counting House, First Floor, Center.	<10/<20
68491	E787 Counting House, First Floor, North Wall.	<10/<20
68492	E787 Counting House, Second Floor, Center.	<10/<20

On the basis of the film-badge measurements, the neutron dose rate was less than 1.3 mrem/h. The gamma dose rate in the E787 counting house was less than 0.6 mrem/h.

Survey Instrument Measurements

A measurement with an HP1010 was made between midnight February 9 and 5 AM February 10 near the LESB III north gate. This is near the chipmunk located at the Class III experimental area for E787. The measurement indicated about 12 mrem/h which is a few mrem/h less than that indicated by the nearby chipmunk.

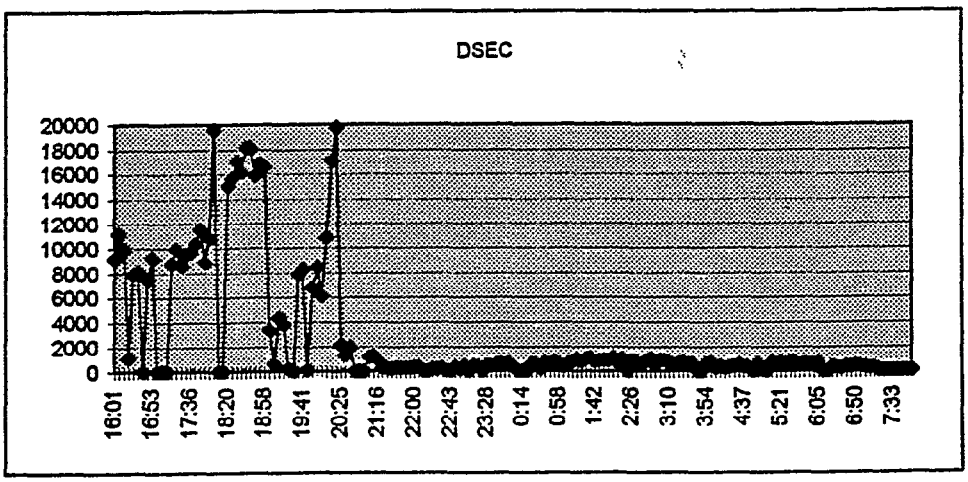
The roadway along side the E787 counting house and the roadway near the C Target Gate measured 2 to 3 mrem/h using the HP1010 survey meter which has a set radiation weighting factor of 5. Given the proximity of water pipes and of Cooling Tower 2, the HP1010 readings should be interpreted as 0.4 to 0.6 mrem/h in this roadway area.

D6, E813

Radiation Weighting Factor Measurements

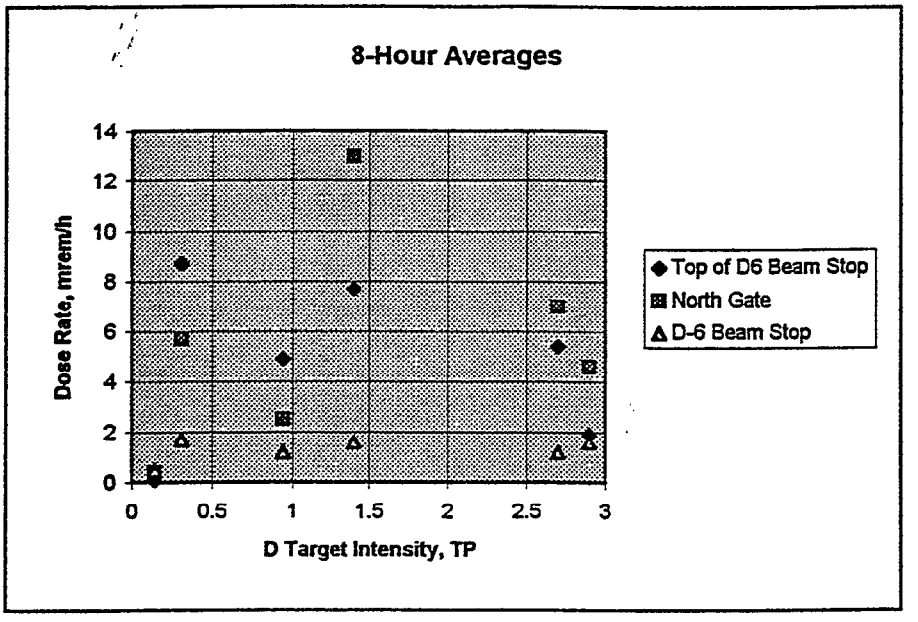
None were made during this study period. During 1994, J. Preisig measured a radiation weighting factor of 6.2 for neutrons in this area. It is noted that neutron dose rates were less than 0.2 mrem/h at the time, and that the total area-radiation-level was dominated by gamma radiation due to shine from water pipes.

Instantaneous Measurements



Average Area Dose Rate and Intensity

Date/Time	D Target Intensity, 8 hour average, TP	Top of D6 Beam Stop, (21) 8 Hour Average, TP	North Gate, (22) 8 hour average, mrem/h	D-6 Beam Stop, (18) 8 hour average, mrem/h
Feb 9, 0 to 8	1.4	7.7	13	1.6
Feb 9, 8 to 4	2.7	5.4	7.0	1.2
Feb 9, 4 to 12	2.9	1.9	4.6	1.6
Feb 10, 0 to 8	0.31	8.7	5.7	1.7
Feb 10, 8 to 4	0.94	4.9	2.5	1.2
Feb 10, 4 to 12	0.14	0.1	0.4	0.5



The dose rates in and around the D Line could not be related in any discernible way to intensity changes on the D target. The D target was minimally used during most of the study period. Changes in dose rates along the D Line may have been influenced by water pipes filled with water from other beam lines. They may also have been influenced by radiation levels in the AGS Ring which is proximate to D Line.

Film Badge Measurements

Badge Number	Location For 16 Hours, Feb. 9 and 10, 1995	Beta Gamma / Neutron Dose, mrem
68481	E813 Counting House.	<10/<20
68478	D Corral Gate	20/<20
68479	North Gate Near Chipmunk 22	40/<20

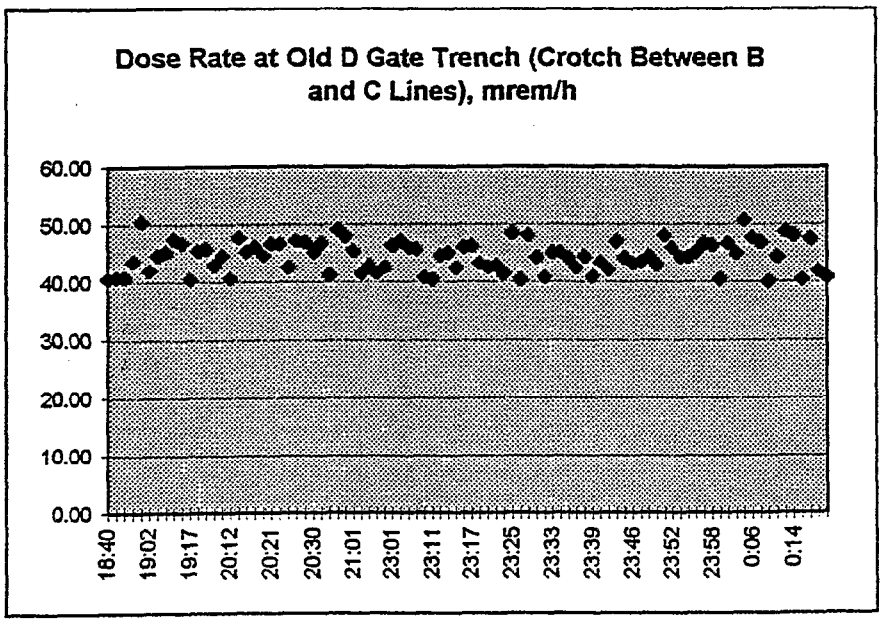
On the basis of the film-badge measurements, the neutron dose rate was less than 1.3 mrem/h. The average gamma dose rate in the counting house was less than 0.6 mrem/h.

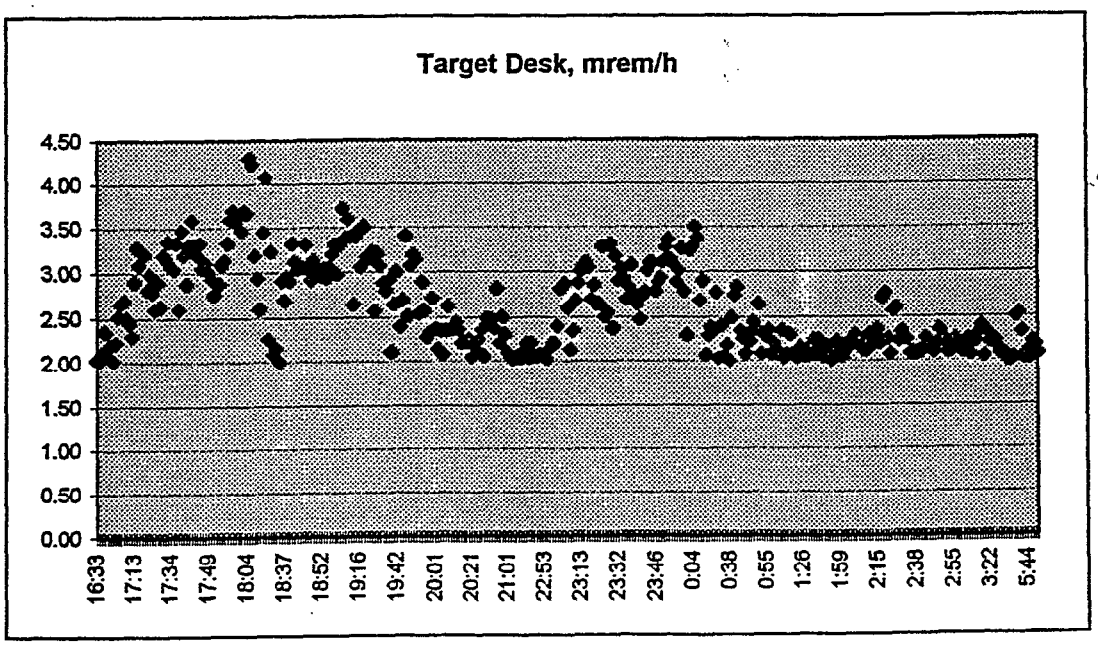
The gamma dose rate at the North Gate to the AGS Ring was less than 2.5 mrem/h on the basis of the film badge measurement. This film badge location was near a water tank. The nearby Chipmunk 22 shows an average of 5.2 mrem/h during this same period. This is in reasonable agreement with the film-badge result if one assumes Chipmunk 22 predominantly sees gamma radiation at this location.

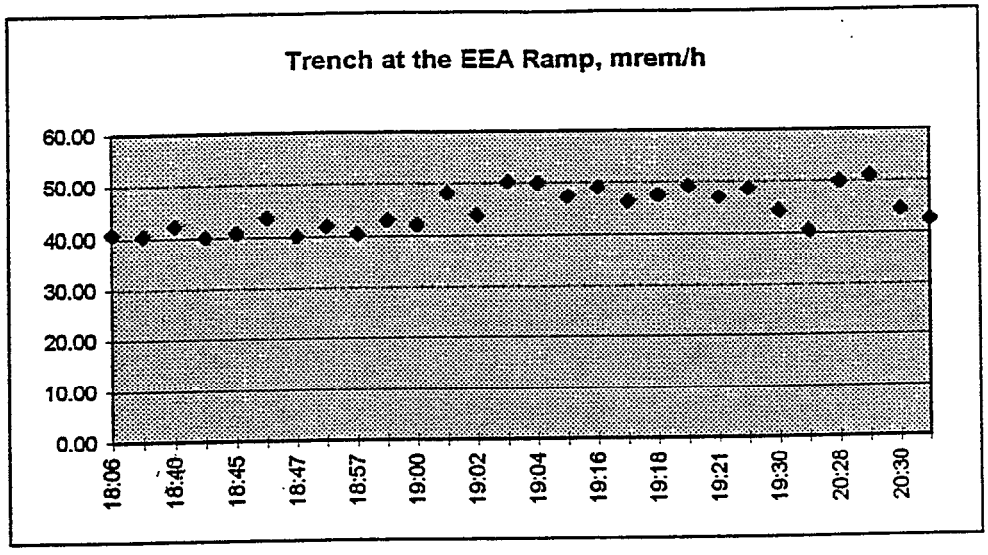
Survey Instrument Measurements

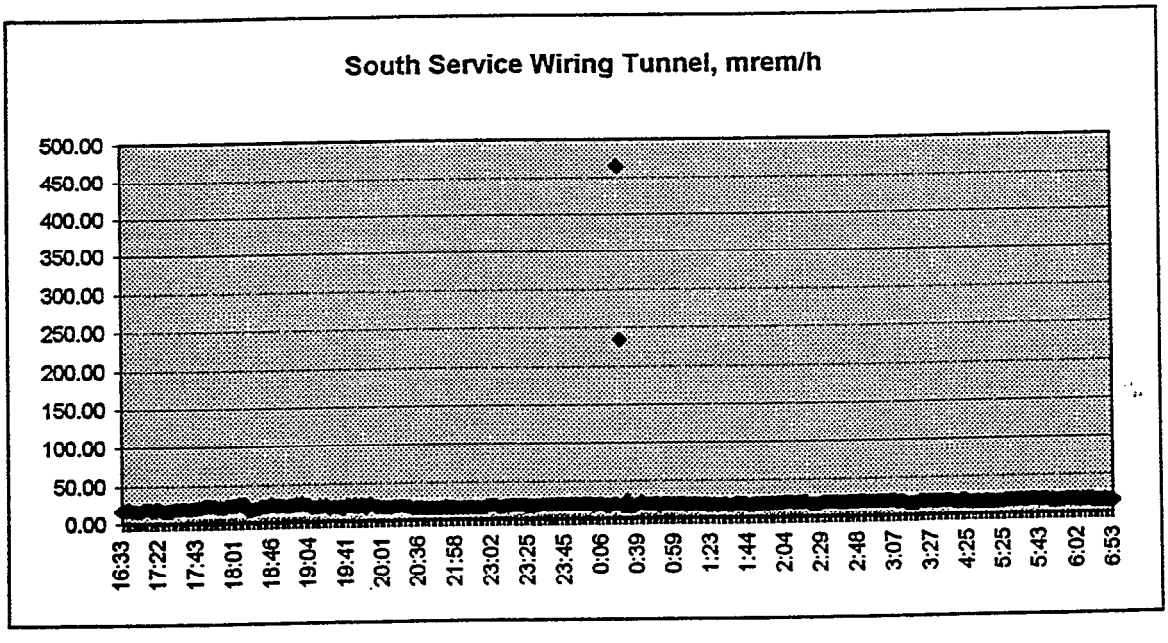
A spot measurement with an HP1010 was made between midnight February 9 and 5 AM February 10 along the D Line. The measurement indicated about 4 mrem/h.

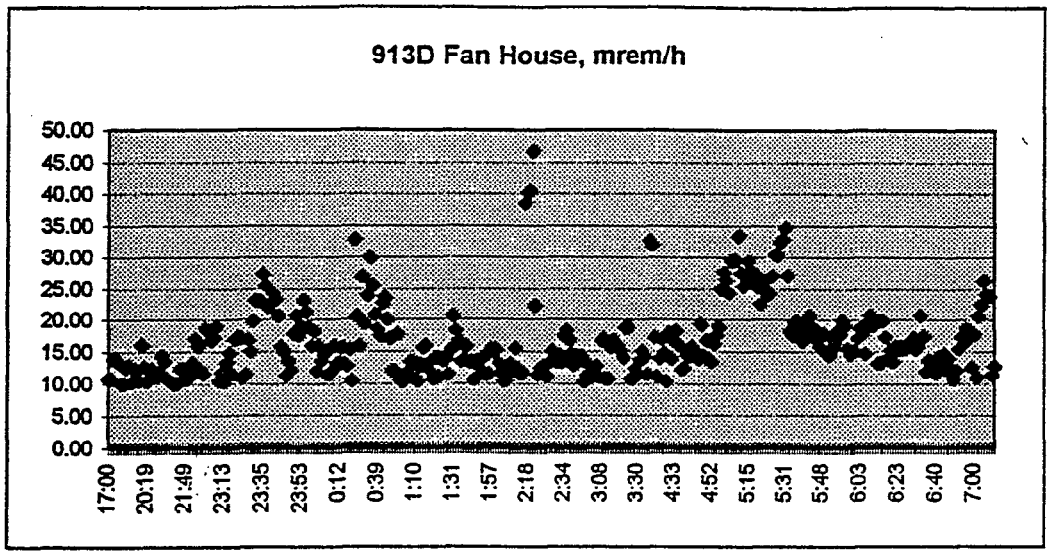
Instantaneous Dose Rate at Hot Spots

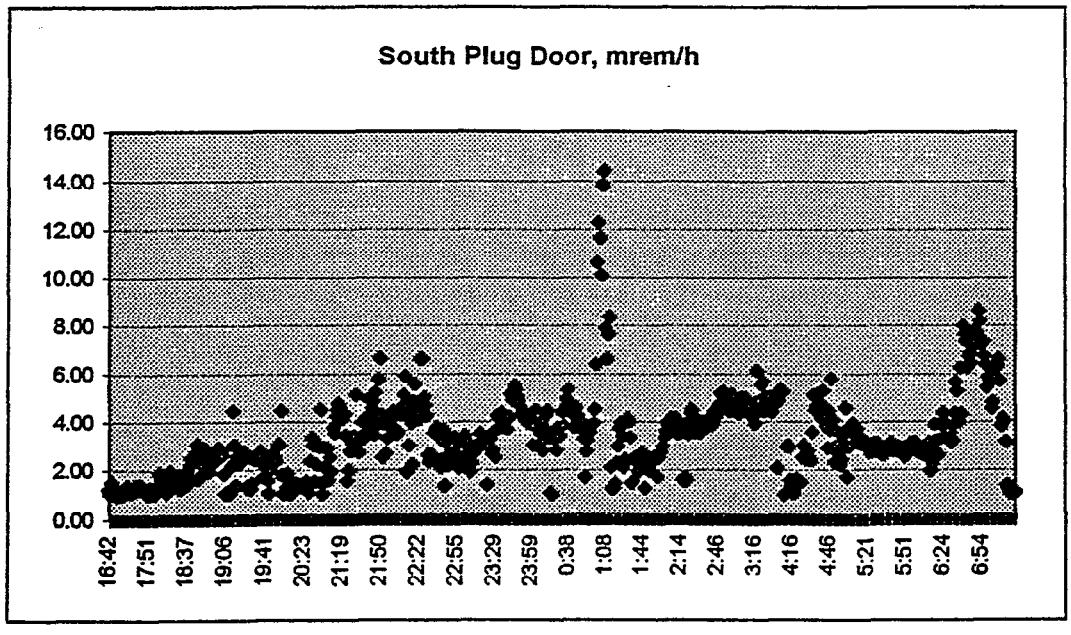


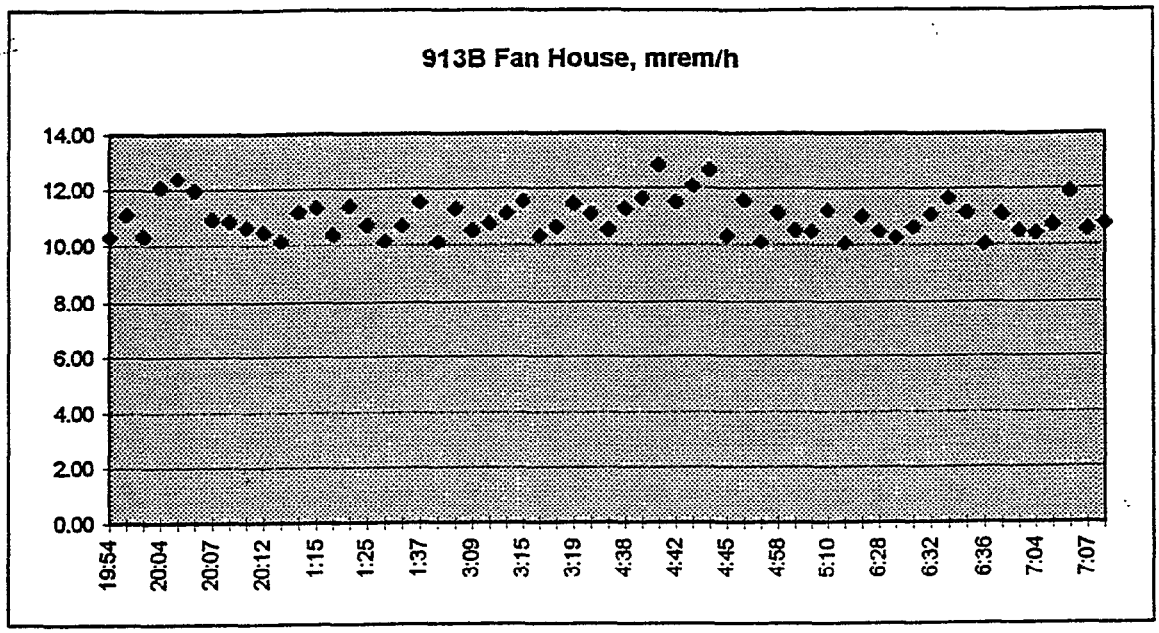


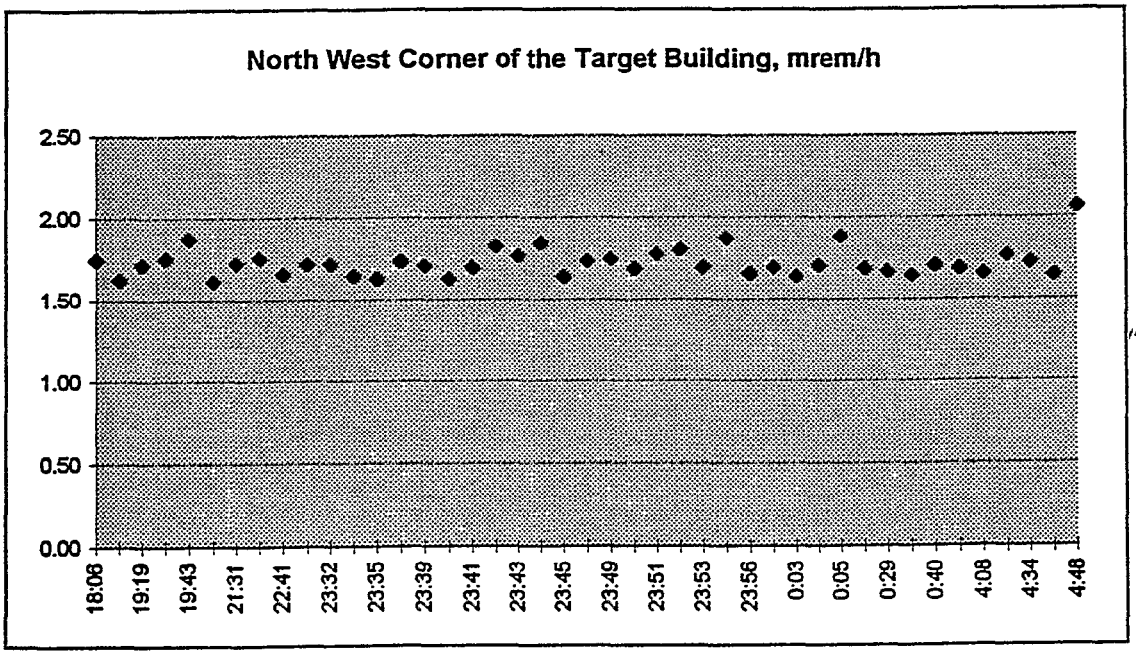

Trench at the EEA Ramp, mrem/h
60.00
50.00
40.00
30.00
20.00
10.00
0.00
18:06
18:40
18:45
18:47
18:57
19:00
19:02
19:04
19:16
19:18
19:21
19:30
20:28
20:30


South Service Wiring Tunnel, mrem/h
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
16:33
17:22
17:43
18:01
18:46
19:04
19:41
20:01
20:36
21:58
23:02
23:25
23:45
0:06
0:39
0:59
1:23
1:44
2:04
2:29
2:48
3:07
3:27
4:25
5:25
5:43
6:02
6:53


913D Fan House, mrem/h
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
17:00
20:19
21:49
23:13
23:35
23:53
0:12
0:39
1:10
1:31
1:57
2:18
2:34
3:08
3:30
4:33
4:52
5:15
5:31
5:48
6:03
6:23
6:40
7:00


South Plug Door, mrem/h
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
16:42
17:51
18:37
19:06
19:41
20:23
21:19
21:50
22:22
22:55
23:29
23:59
0:38
1:08
1:44
2:14
2:46
3:16
4:16
4:46
5:21
5:51
6:24
6:54





Film Badge Measurements at Hot Spots

Badge Number	Location For 16 Hours, Feb. 9 and 10, 1995	Beta Gamma / Neutron Dose, mrem
68497	Switch Yard Trench	20/40
68498	Target Building Ramp, Chipmunk 01	40/40
68499	Target Building Ramp, Chipmunk 38	50/<20
68500	South Service Wiring Tunnel	110/90

On the basis of the film-badge measurements, the neutron dose rate at the South Service Wiring Tunnel was about 5.6 mrem/h. The gamma dose rate at the South Service Wiring

Tunnel was 6.9 mrem/h on the basis of the film badge measurement. Because of a pre-set radiation weighting factor of 2.5, the 6.9 mrem/h gamma dose rate would be recorded as 17 mrem/h on the chipmunk. However, this particular chipmunk registered an average of about 15.8 mrem/h during this period. Thus, in this case it appears the film badge recorded an 'extra' neutron dose of 90 mrem. This is peculiar since this chipmunk was known to be located next to water pipes where the gamma rays dominate the radiation field.

The gamma dose rate at the trench that crosses the Target Building Ramp is 2.5 mrem/h as indicated by film badge 68498. The chipmunk results indicate a 16-hour average gamma plus neutron dose rate of about 19.7 mrem/h at Chipmunk 01. Because of a pre-set radiation weighting factor of 2.5, the 2.5 mrem/h gamma dose rate indicated by the film badge would be recorded as 6.25 mrem/h on Chipmunk 01. Thus, the remaining 13.5 mrem/h at Chipmunk 01 would be attributed to neutrons. The film badge indicates an average neutron dose rate of 2.5 mrem/h. If one assumes the gamma results on film badges are reliable, then either this film badge 'missed' a neutron dose equivalent of 175 mrem or the Chipmunk over-responded to the mixed radiation field.

Film badge 68499 near Chipmunk 38 was also on a trench and indicates that all the radiation 'seen' by Chipmunk 38 should be attributable to gamma radiation. This is peculiar since the trench locations are known for mixed neutron and gamma radiation fields.

Airborne Radioactivity From Cooling Tower 2

Cooling Tower Plumes

The cooling-water system emissions to air from Cooling Tower #2 (CT2) are described herein. This year, the AGS is aiming for $6x10^{13}$ protons per pulse with 1 pulse every 3 seconds for 20 weeks. Normally, this beam is spread among four beam lines.

There are four cooling towers that cool the water from magnets in experimental areas in Building 912. Currently, the radiation levels at CT2 are 20 to 100 times greater than the levels at the other three towers. The difference is due to higher than normal proton-beam interactions in the C Line, the small volume of the CT2 water system, and the high flow rate being used to cool the C-Line magnets. The water in the cooling system is exposed to air as it moves through the cooling tower about 10 m off the ground. Some water is added as make up due to losses, but most of the water ends up back in the magnet cooling system via piping back from the tower.

The cooling water for targets is connected to a heat exchanger system. Cooling towers do not see cooling water from targets directly.

The activity-production rates (kBq/s) in water in CT2 for the short-lived nuclides O-14, O-15, N-13 and C-11 are given by Sullivan for $1x10^{12}$ high energy hadrons traversing 1 cm water per second, and are as follows.[1] I write them in the units used by Sullivan. They may be converted to atom-production rates using the decay constant.

Nuclide	O-14	O-15	N-13	C-11
Half life, minutes	1.2	2.1	10	20
kBq/s per 10^{12} hadrons/s	$3.20x10^{2}$	$7.30x10^{3}$	$3.20x10^{2}$	$9.00x10^{1}$
λ, s^{-1}	$9.60x10^{-3}$	$5.50x10^{-3}$	$1.16x10^{-3}$	$5.78x10^{-4}$

The short-lived gamma-emitting nuclides O-14, O-15, N-13 and C-11 reach equilibrium activity in the water systems within minutes. Thus, the atom production rate equals the equilibrium activity for these nuclides.

The CT2 system has a volume of 3000 gallons ($1.1x10^{7}$ cm^3) and a flow rate through the tower of 1500 gallons per minute. Thus, not much decay occurs between the time the radionuclides are produced and the time taken to reach the tower. Because of the duration of target bombardment, equilibrium activity ratios for the short-lived nuclides in the tower cooling water would apply here. The measured exposure-rate levels during an August 1994 run with $1x10^{13}$ protons per pulse on the C target indicated the following estimates of equilibrium activity concentrations in the pipe:

Exposure rate at inlet pipe at the cooling tower (CT2)	O-14	O-15	N-13	C-11
	$\mu Ci/cm^3$	$\mu Ci/cm^3$	$\mu Ci/cm^3$	$\mu Ci/cm^3$
9.0 mR/h measured at contact	$3.9x10^{-4}$	$1.5x10^{-2}$	$3.2x10^{-3}$	$1.9x10^{-3}$

Recent measurements made by Miltenberger in the afternoon on February 9, 1995, have shown the estimated emanation rate of C-11 and O-15 from CT2. The 8-hour average intensity in C Line at the time was about $0.8x10^{13}$ protons per pulse; that is, similar to the proton levels in August 1994. The levels in air in the plume just above the tower were measured to be $7.4x10^{-7}$ $\mu Ci/cm^3$ for C-11 and $5.8x10^{-6}$ $\mu Ci/cm^3$ for O-15. This indicates a transfer to air of about 0.04% for C-11 and 0.04% for O-15. These activity concentrations also correspond to an exposure rate of 5 mR/h if one is standing in this plume at the top of the tower.

The ratio of flow rate to system volume for this AGS cooling system is very high due to the current need to cool the magnets in C Line, and is 0.0083 s^{-1}. On the basis of measurements made, 0.04% transfer of gas to air occurs whenever the water is in the cooling tower. Thus, a removal rate constant for these nuclides to air of 0.0000032 s^{-1} is derived.

[1] A. H. Sullivan, A Guide to Radiation and Radioactivity Levels Near High Energy Particle Accelerators, Nuclear Technology Publishing, Ashford, Kent, TN23 1JW, England (1992).

The following activity release rates were estimated using the derived removal rate constant and the estimated activity in the system:

Nuclide	O-14	O-15	N-13	C-11
Activity Release Rate to Air, μCi/s	0.014	0.53	0.11	0.068

The site boundary is 1400 m away. A wind speed of 3 m/s is used to account for decay in transit to the site boundary. On the basis of wind-rose data for the BNL site, the wind blows in any one direction as much as 10% of the time. Between 100 and 2000 m, the ratio of air concentration to activity release rate varies by as much as two orders of magnitude for a constant wind speed and a 10 m release height. This variation is denoted by Pasquill diffusion categories A through F. At 1400 m, the ratio of ground-level air concentration to activity release rate ranges from $1x10^{-12}$ to $1x10^{-10}$ s/cm^3.[2] At 100 m, the range is $3x10^{-11}$ to $5x10^{-10}$ s/cm^3.

At 100 m, exposure rates of 20 to 25 μR/h have been measured at ground level. On the basis of activity concentrations at CT2 measured by Miltenberger, this would suggest a ratio of air concentration to activity release rate on the order of $4x10^{-8}$ s/cm^3. This is about two orders of magnitude higher than that calculated by the range of meteorological factors using Pasquill categories. However it is within the realm of reason considering the plume may loop back on itself during periods of low wind-speed. Also the proximity of Buildings 912, 911, 918, 923 and 922 to CT2 would tend to trap the plume and decrease the turbulence or movement of air. These fumigating or looping conditions are not accounted for in the Pasquill categories and are considered to be 'close-in' effects.

Accounting for 'close-in' effects, the range of activity concentrations at ground level is estimated as follows:

Nuclide	O-14	O-15	N-13	C-11
Range of Off-Site Air Activity Concentration, μCi/cm^3				
High	$2.5x10^{-16}$	$3.8x10^{-13}$	$3.9x10^{-12}$	$4.0x10^{-12}$
Low	$2.5x10^{-18}$	$3.8x10^{-15}$	$3.9x10^{-14}$	$4.0x10^{-14}$
Range of Air Activity Concentrations at 100 m, μCi/cm^3				
High	$7.0x10^{-10}$	$2.7x10^{-8}$	$5.5x10^{-9}$	$3.4x10^{-9}$
Low	$4.2x10^{-13}$	$1.6x10^{-11}$	$3.3x10^{-12}$	$2.0x10^{-12}$

[2] David Slade, Editor, Meteorology and Atomic Energy, Technical Information Center, U.S. Department of Energy, TID 24190 (1968).

Limited ground-level exposure rate measurements have been made and the calculated rates at 100 m may change by a factor of 2 to 3. However, the current expectation values for dose-equivalent rates for a semi-infinite cloud of gas are as follows:

	High	Low
Range of Site Boundary Dose Equivalent Rate, mrem/h	0.0000089	0.000000089
Range of Dose Equivalent Rate at 100 m, mrem/h	0.038	0.000023

The wind is in any one direction for up to 10% of the time or 2 weeks out of the 20 week running period. For a person located in any single downwind direction, the range of annual dose at that location is:

	High	Low
Site Boundary Annual Dose Equivalent, 168 Hour Week, mrem	0.0030	0.000030
Annual Dose Equivalent at 100 m, 40 Hour Week, mrem	3.0	0.0018

Status of the Measurements

With regard to the dose from the cooling water towers, the S&EP FSS has set out 25 TLD dosimeters which would measure the low doses predicted by the plume extrapolations. The TLDs are located throughout the occupied offices of Building 911. It is expected that supporting results would be obtained in a period of several weeks.

With regard to neutron quality factor measurements, all but the A2 and C1 areas have been measured recently. All other areas that are occupied during proton running appear to have been studied in the recent past. The pre-set value of Q=2.5 for chipmunks appears adequate for the mixed radiation field in most experimental areas, but is not appropriate for chipmunks located next to water manifolds.

Key Issues

Priority of issues:

1. Occupancy of counting houses should be such that Users plan to receive no more than 500 mrem during the HEP running period.
2. Radiation dose to on-site personnel from plumes from cooling towers needs to be characterized better and be lowered where practicable.
3. Shielding should be upgraded to the level that uncontrolled areas receive no more than 100 mrem per year assuming 5% occupancy (e.g., the areas outside escape hatches and the South Plug Door).
4. Shielding in Controlled Areas should be upgraded for ALARA purposes and for compliance with Radiation Area requirements during future FEB running (e.g., North Catwalk and North Plug Door).
5. Chipmunk alarms in the MCR should only be used to alert operators of potentially hazardous conditions (e.g., the chipmunk in the C2 Class III

experimental area should not alarm when the area is reset and unoccupied).

6. Chipmunk quality factors of 2.5 for areas dominated by gamma exposure from water manifolds are not appropriate.
7. The posted radiation level does not always reflect the correct proportion of gamma and neutron dose.

Next Steps

Summary of Past Actions

The AGS and pertinent S&EP staffs have undertaken studies of neutron dose and gamma dose rates in and around the AGS Complex for high-intensity proton running. The relationship of dose rate to machine intensity, and the neutron and gamma components of the radiation field were studied. The use of various radiation-weighting-factors was reviewed. Airborne contamination at the Target Gates and radiation exposure from a cooling tower plume were observed and measured.

Specific Future Actions

1. Add shielding to trenches at the EEA Ramp and the trench running through the Old D Gate Crotch. A factor of 2 to 3 may be achieved on the basis of experience with other trenches. This should be a Radiation Safety Committee (RSC) Action Item.
2. Reduce occupancy in the B5 Condo or better shield the Condo. Plan for less than 80 hours per month at 20 TP or move the counting house. The liaison physicist for the B5 Line should give this matter high priority.
3. Change the set point of B5 Ledge Alarming Chipmunk to 50 mrem/h. This has been completed by the RSC.
4. Reduce the occupancy at the Target Desk. This has been completed by the Head of the EP&S Technical Support Group.
5. Chipmunks in secured Class III areas that are continuously in the alarm state should be evaluated for a new alarm set point, or the limited MCR response to such an alarm be outlined in a written procedure. The replacement for the PDP10 computer should be programmed to distinguish when an area is reset and not occupied. The RSC should address this issue with an Action Item.
6. Shield the South-Service-Wiring-Tunnel chipmunk from water-pipe radiation while ensuring it will react properly to beam faults. This has been completed by the RSC.
7. The shields around AGS Ring escape hatches should be upgraded. This should be preceded by a review of the dose-rate relationship between the escape hatches and the Fan Houses. This is a Radiation Safety Committee work-in-progress. Additional shielding requests, if

necessary, should be submitted as a future GPP project by the AGS Associate Chair for Safety.

8. The shielding near the South Plug Door should be upgraded. This is a RSC work-in-progress.
9. The shielding at the North Plug Door should be upgraded. This is a RSC work-in-progress.
10. The North Catwalk shielding should be upgraded. This should be preceded by a review of the dose rate during future FEB running. Additional shielding requests, if necessary, should be submitted as a future GPP project by the AGS Associate Chair for Safety.
11. Efforts should be undertaken by the S&EP FSS and the RSC to ensure the gamma dose rates and the neutron dose rates are accurately reflected on survey maps and postings.
12. The S&EP Health Physics Group should perform Bonner Spectrometer measurements for quality factor in the A2 and C1 Lines for proton running.
13. Environmental TLDs should be placed in offices in Building 911 and other similar areas in order to fully characterize the gamma shine from the cooling tower plumes. This is an S&EP Division work-in-progress.
14. The ad hoc AGS Hot Water Committee Chair should be apprised of recent measurements on or near cooling waters, and review long-term and short-term options for dose reduction. The Committee has begun the review and this is a work-in-progress.